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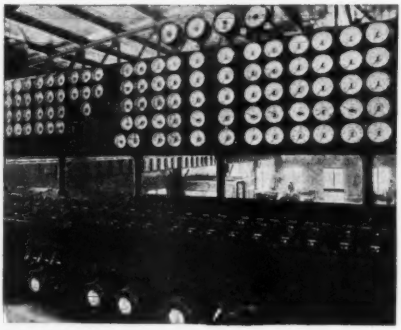

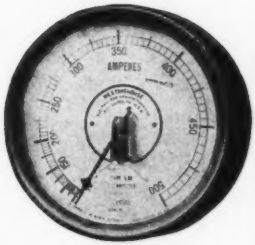

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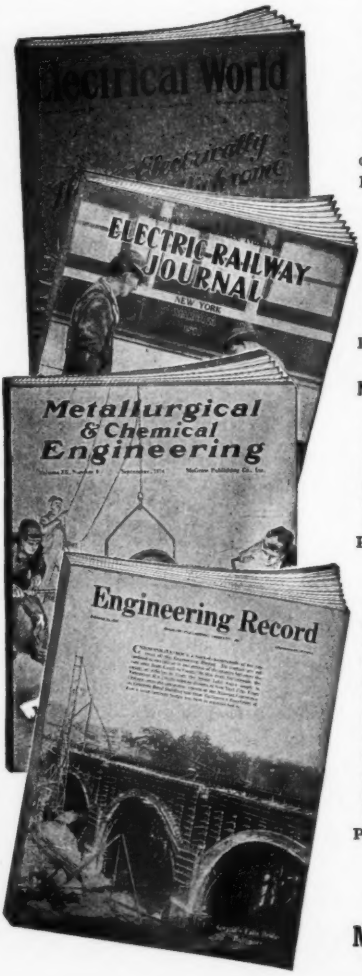

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TABLE OF CONTENTS.

The Relaton of Mathematical Training to the Engineering Profession. By H. D. Gaylord and Paul H. Hanus 54
The English Department and the Professional Schools. By Homer A. Watts 73
Some Simple Demonstration Experiments in the Elementary Presentation of Elasticity. By W. S. Franklin and Barry MacNutt . 90
Engineering English at the University of Michigan. By J. Raleigh Nelson 101
What Is Industrial Engineering? By P. F. Walker 108
Discussion of "Aptitute as a Basis for Education." By J. R. Benton 111
Discussion of "Income of Engineering Graduates." By L. H. Rittenhouse 115
Discussion of "An Experiment in the Evaluation of an Integral." By L. M. Passano 118
Report of the Auditing Committee 119
Editorial 120
Comments on the Virginia Meeting 120
New Members 123
Applicants for Membership 123
Personal 124
Book Review 124

THE RELATION OF MATHEMATICAL TRAINING TO THE ENGINEERING PROFESSION.

BY H. D. GAYLORD,

Secretary, Association of Teachers of Mathematics in New England,

AND

PAUL H. HANUS,

Professor of Education, Harvard University.

In order to determine whether the successful engineer, after reaching some eminence in his profession, agrees with the requirements of the engineering colleges, letters were sent to 95 electrical, mechanical, civil, and illuminating engineers. These men were reached through the coöperation of the engineering societies and the employers of large numbers of engineers in these various fields. In this way a wide geographical distribution was obtained, and also some assurance that careful consideration would be given to the inquiry.

The letter was a request to answer the following questions:

1. Which of the following subjects do do you consider *essential* to the equipment of a (mechanical) engineer? Check in column 1.
2. Check in column 2 other subjects in this list which you consider *desirable training* for the engineering profession.
3. Please add here any comments which you may wish to make on the general subject of this investigation.

	1.	2.
Arithmetic		
Algebra		
Plane geometry		
Solid geometry		
Trigonometry		
Analytic geometry		
Calculus (1st year)		
Calculus (2d year)		
Spherical harmonics		
Fourier's series		
Vector analysis		
Differential equations		

The fact that 75 letters were checked and returned, together with the fact that 47 contained more or less extended discus-

sions of the question, ranging from one line to two pages, makes it probable that the majority of the replies contained the carefully considered data desired. There were 33 electrical, 25 mechanical, 9 civil, and 8 illuminating engineers who answered these letters, and these men were distributed over a wide area including eastern, southern, middle west, and western states. This wide distribution, geographically and professionally, and the care with which the answers were evidently prepared, make the data obtained a fair representation of engineering opinion.

The following is a table of the results as given by the checking of the questions:

	Electrical.		Mechanical.		Civil.		Illuminating.		Totals.		
	Essential.	Desirable.	Essential.	Desirable.	Essential.	Desirable.	Essential.	Desirable.	Essential.	Desirable.	Neither Essential nor Desirable.
Arithmetic	33	0	25	0	9	0	8	0	75	0	0
Algebra	31	2	25	0	9	0	8	0	73	2	0
Plane geometry	29	4	25	0	9	0	8	0	71	4	0
Solid geometry	25	7	23	2	9	0	6	2	63	11	1
Trigonometry	31	2	24	1	9	0	8	0	72	3	0
Analytic geometry	22	9	19	3	7	2	7	1	55	15	5
Calculus (1st year)	16	15	15	8	4	5	8	0	43	28	4
Calculus (2d year)	12	16	11	10	4	5	4	4	32	35	8=11%
Spherical harmonics	0	12	0	7	0	2	0	5	0	26	49=66%
Fourier's series	4	12	0	8	0	2	0	5	4	27	44=58%
Vector analysis	6	15	4	8	0	2	1	5	11	30	34=45%
Differential equations	6	12	2	10	1	4	2	3	11	29	35=47%

From the last column of the above table, we find that 45 per cent. of the engineers consulted believe that no mathematics beyond the second year of calculus is either essential or desirable for training. This seems to be for two reasons which are brought out more clearly in the supplementary opinions expressed in the letters.

First, the study of the higher branches of mathematics, even were it possible in the limited time given to thoroughly master the subjects involved, develops the theoretical side of the engineer's education too much in advance of the practical. He

is, on this account, unqualified to appreciate the great preponderance of the physical conditions involved in his problems. His excessive faith in his theoretical knowledge leads him to attempt its blind application to physical conditions, looking for a chance to apply the theory rather than for an interpretation of the physical conditions. This point of view is brought out in the following quotations from these letters:

"By the time they have got through calculus, they have gone over more mathematics than they can apply or interpret in the physical world."

"Arithmetic and geometry are about all the average graduate can apply to physical problems. His surplus above that up through calculus will last him for many years of development."

"I would say, don't go beyond calculus in college. Wait until your practice catches up with your theory. Then if you need more mathematics in your business, take all you can assimilate."

"I have come in contact with hundreds of young men who have been given an engineering training in some of our best schools, who could not see anything in the way of physical facts or phenomena except through the medium of the mathematical expression. This is exceedingly unfortunate, as it plainly shows that the men had been impressed more with the value of the mathematical study and mathematical training than with a good physical grasp of problems."

"The 'direction of natural forces to the benefit of mankind' —which is the engineer's function—is not a matter that rests primarily on mathematics."

"A developing mind must not pursue pure theory in any subject to a degree that prevents the mind from being readily receptive to the broad general principles underlying daily practical work."

Hence it would appear that in the opinion of some of the most successful engineers, the excess of theory involved in the higher mathematical branches is not only unnecessary to the

profession, but actually hinders the young engineer in his progress toward success.

The second reason is the conviction that the mental training, if any, produced by the study of the higher branches of mathematics for those who are not ready to use them as tools, would be more valuable if produced by "design" or "investigation." The remoteness of the opportunity to apply the theory acquired, except for those engaged in research or theoretical work, makes the study of these higher branches a wasteful expenditure of time and energy at the beginning of a career. This point of view is illustrated by the following quotations:

"While the mental training provided by the other mathematical branches would not be wholly lost, the time and mental energy might be used to better advantage in more practical lines, as design or some engineering investigations."

"The writer is becoming impressed with the idea that the function of the engineering college is to teach men how to think and how to analyze and how to observe and how to deduce conclusions, rather than teaching them any particular facts. The vehicle through which they learn 'how' is of very secondary importance."

"Spherical harmonics and Fourier's series are so highly special that it seems best to defer study thereof until actual individual need is foreseen."

"These subjects (spherical harmonics, Fourier's series, vector analysis, differential equations) are desirable to about the same degree as any other subject pertaining to a liberal education: *e. g.*, Psychology, Greek."

The remoteness of the opportunity to apply the theory or facts or methods of attack acquired in the study of the higher branches of mathematics would seem, then, to be a reason for rejecting these courses as either essential or desirable. This remoteness of opportunity to apply the knowledge takes away from these subjects much of the value which we might expect to find there on account of their more or less intimate relation

to some of the theoretical sides of Engineering. The training in analyzing, observing, and deducing conclusions from the kind of data which the engineer has to consider, cannot be obtained through the study of a subject which does not involve the kind of data in question, except in so far as ability acquired in reasoning about one subject may be automatically transferable and thus be used in reasoning about a different subject.

It is evident then, that in the opinion of these men, *training in ability to deduce conclusions from data* is the most important thing to be accomplished in the engineering course outside of the practical knowledge about engineering itself. The subjects in question, therefore, must stand or fall on their efficiency in producing this ability. And the slight application of these subjects to the early career of the engineer seems to argue that they are not especially adapted to this purpose.

It might be expected that those engineers who had never taken the second year of calculus would be the ones who are not in favor of more than a first year of the subject. Those educators who have planned the courses in the engineering colleges would certainly hope that the men who had taken two years of calculus should be convinced of the essential nature of the subject matter in an engineering course. It seems, however, that in the ten cases where the engineers questioned are known to have graduated from such high grade institutions as the University of Michigan, Massachusetts Institute of Technology, Rensselaer Polytechnic Institute, there were seven who believed no calculus at all is essential. Four of these would require nothing beyond trigonometry.

It would thus appear that the prejudice against calculus and analytic geometry as essential tools for the engineer is not wholly due to lack of training in these courses. This is more strikingly true when we find that of the 32 who considered no calculus essential, at least 7 are known to be graduates of schools where more than one year of calculus is required.

The engineering colleges call for one year of calculus, as the

minimum of mathematics for graduation in engineering. From the above table we see that only 56 per cent. of the engineers believe one year of calculus to be essential. We may say then, that the engineering schools have failed to persuade about half the engineers reached by these letters that even one year of calculus is essential to their success.

In analyzing this fact we must again consider the question of the purpose of the mathematical courses in the preparation for the engineering profession. The question arises whether these courses are intended as tools or as general mental training, or as both. Here we must contrast the opinions of three classes of critics.

First, the engineers themselves for the most part consider these elementary subjects as tools. The following quotation is an illustration: "To the engineer, mathematics should be taught as a useful tool, and not as an interesting pastime, or as mere mental gymnastics." Second, the mathematicians consider the mental training an important part of all mathematics, and deplore the tendency to determine the value of a subject on the basis of its practical applications. Third, many psychologists believe that mental ability cannot be automatically transferred, and hence, that the study of mathematics can give ability only for more study of mathematics. The psychologist will thus agree with the engineer that mathematics should be studied only as a tool, since, in general, there will be no transferable mental ability acquired. If this transfer cannot be made, the study of *any* subject requiring reasoning ability will train the student as effectively as the higher branches of mathematics, unless these branches contain the elements of applicability which can be made appreciable to the student at the time he is studying them.

It is fair to assume that the mathematics through a first year of calculus is given by the engineering schools because they believe that it is needed by the student for the purpose of understanding the various engineering courses he is studying. It may be admitted that this thorough understanding of the

theoretical engineering courses is not necessary in the actual practice of the engineering profession. In fact, the educator is well aware that the actual problems arising in the engineer's experience may never involve the necessity of applying the details of calculus to the question in hand. He feels, however, that some knowledge of the methods involved in developing the theory upon which the problem depends, perhaps the method of deriving the hand-book formula which solves the problem, in some way gives the engineer who has this knowledge a distinct advantage over his less fortunate brother.

Only five engineers expressed an opinion which could be interpreted as faith in the mental training to be derived from the study of mathematics. One says, "In comparison with the total, the amount of electrical engineering work requiring any extensive knowledge of higher mathematics, is relatively small and courses in it, if considered essential, are essential largely from the training standpoint." This would indicate rather a conviction that these subjects are not very valuable as tools, than that they have any value as mental training. The others are, however, more positive in their opinion, as for instance the following: "The average electrical engineer uses very little of the so-called 'higher mathematics' in his business, but the training received in studying them is very valuable." "An engineer could get along without the last three (analytic geometry, calculus—two years) but even though he does not use these subjects in actual practice, I believe the mental training worth the effort." The fourth implies the mental training in this sentence, at the end of a more extended remark: "For the real professional engineer, as I conceive him, there is no limit to the amount of mathematics which is good for him." The fifth, however, leaves no doubt as to his faith in the training power, when he says: "Mental gymnastics is an essential for the development of the young engineer. If his mind does not readily respond to these exercises, he had better change his profession."

We may say, then, that at least those subjects in the list

including a first year of calculus are generally accepted as tools rather than as training by the majority of the engineers and by many of the educators. The report of the committee appointed by the Society for the Promotion of Engineering Education also indicated that they considered these subjects as tools for the engineer, rather than as mental training; for they have put into the form of a syllabus the topics in these subjects which they feel should be thoroughly familiar to a student of engineering. To quote from a preliminary draft of the syllabus: "The syllabus is intended to include those facts and methods of elementary geometry which a student should have so firmly fixed in his memory that he will never think of looking them up in a book."

Considered, then, as tools, these subjects will be more or less valuable according to the thoroughness of the student's knowledge of each. This necessity for thoroughness is one of the reasons why many engineers are in favor of only a few mathematical subjects.

This point is illustrated in the following quotations: "I cannot emphasize too strongly a thorough knowledge of mathematics for engineering work. I believe, however, that it is more advisable to have a very thorough knowledge of a few mathematical subjects than a mediocre knowledge of a large number."

"The training in arithmetic, algebra, plane geometry, and trigonometry cannot be too complete."

"Likewise, arithmetic, algebra, geometry, trigonometry, and calculus should not be in the least slighted in order to make room for spherical harmonics and Fourier's series."

"The weakest point in the ordinary teaching of mathematics is the neglect of thorough instruction in algebra. The ordinary student for this reason alone finds analytic geometry, calculus, etc., difficult, and seldom gets a real grip on them."

A thorough knowledge of the elementary mathematics, which will enable the engineer to make these subjects really useful tools, is evidently what these men consider most es-

sential. For this reason apparently, only 57 per cent. believe a first year of calculus essential, and 27 per cent. believe that no mathematics beyond arithmetic, algebra, geometry, and trigonometry is essential. That is, more than one quarter of those consulted believe that no mathematics beyond what a well equipt high school can furnish is essential to the preparations of the engineer.

This lack of thoroughness in the knowledge of the elementary subjects causes one of those who offered supplementary opinion to feel that if he had a more thorough understanding of calculus, he might find it of much use in cases where he now resorts to algebra and trigonometry and hand books. He says: "I don't dare to use anything beyond trigonometry where there is much money involved, and I look it up in the book at that. I use the fundamentals of mechanics a thousand times where I use calculus once. If I could use my calculus on those principles, no doubt I should get along a good deal faster."

Another says: "My general view is to give all engineering students as much mathematics as they can absorb. I hope I am not wrong in my impression, based on experience, that usually so much is attempted that none is really understood and little retained."

Thoroughness of preparation in those elementary subjects which can be called tools in the engineer's profession, and postponement of the advanced subjects which in the college career of the student would be theoretical and valuable only as training, to a time when they, too, may be required as tools in the more mature experience of the engineer, is the most obvious conclusion to be drawn from the opinions expressed.

The more detailed study of these letters brings out the fact that the engineer finds the mathematical courses unsatisfactory, because they place more emphasis upon those methods and subjects which are purely mathematical than upon the applicability of the subject matter to the solution of problems characteristic of engineering. They maintain that the inter-

est of the prospective engineer in the development of a piece of mathematical theory, is not primarily in the mathematical reasoning involved. Although it is not desirable that the mathematical courses should be made up of so-called practical problems drawn from engineering practice, still the engineer's primary interest is in the *result* of a solution and not in the elegance of a given method of solution as compared with a more crude and more transparent method. The interest of the mathematician, however, is in the refined methods and reasoning involved in a given subject. A course in calculus or analytic geometry, for example, may be given with much emphasis on the mathematical development of the subjects, the various methods of defining the curves, and the various refinements in the different proofs for a given theorem; or it may be given with much emphasis on the "plotting of equations and determination of laws from results of experiments," and on the expression of physical conditions in mathematical terms. Differential equations may be studied for the purpose of learning to classify such equations and find the most elegant method of solving each; or for the purpose of expressing electrical conditions in the form of differential equations in order to make the interrelations among these conditions more transparent—the methods of solution being a secondary matter.

The question is, of course, one of the relative amounts of emphasis placed upon these two phases of the mathematical course. Relatively strong emphasis on the applications of mathematical theory to the problems arising in practice is what the engineers desire. Relatively strong emphasis on the theoretical side of mathematics seems to be what the mathematics departments are offering. Hence the contention by the engineers that for the purpose of preparing students to enter the engineering profession, more emphasis should be given to the applications of mathematics and less to mathematical theory. Of course no general conclusion can be drawn from the fact that a given engineer thinks that too much emphasis was placed on mathematical theory in the course

which he took. We cannot criticize mathematics departments in general because a few fail to appreciate the needs of engineering students.

For this reason, much care was taken in sending out the present inquiries to include widely different parts of the country and to include many engineers who have received their training within the last ten years. The latter precaution enables us to avoid conclusions which might be true of mathematical courses twenty-five years ago, but which are no longer true because of changes in the methods of teaching. In view of this precaution it is interesting to note that from five different fields widely distributed both geographically and professionally, comes the testimony that unless the courses can be given with more emphasis on the applications, no mathematics beyond trigonometry is essential. These engineers were all graduated since 1900 from prominent engineering colleges including one eastern, two middle western, and one Pacific slope college. Two of them were graduates of both a Pacific slope college and a prominent eastern engineering college, and have acquired sufficient eminence to have many engineers in their employ. The testimony on this point may be taken, therefore, with some confidence as reflecting recent conditions both from personal knowledge and from observation.

About 20 per cent. of the engineers reached by this inquiry *i. e.*, 2 civil, 4 mechanical, 1 illuminating, and 7 electrical, urged more emphasis on the application of mathematics for students of engineering; the five above mentioned being only those whose college training was known to be of the highest quality and of recent date.

Those engineers who expressed opinions on this subject are usually emphatic in the opinion that the engineering courses should not be wholly commercialized by offering only those branches which could be immediately used as tools in the profession. At the same time, they believe that the ability to analyze and draw accurate, logical conclusions from given data in the field of engineering can be developed by the study

of other subjects less remotely connected with the engineer's interests than are the theoretical parts of pure mathematics. We have from these letters such quotations as the following: "The developing mind must not pursue theory to the detriment of, but rather to the support and advantage of, practice." "All mathematics for engineers should be taught as a tool for sciences and engineering; not as an end in itself. Reducing formulas to graphical charts is an important time saver."

"I would recommend strongly that in connection with all courses given, numerous problems of engineering application should be included. In this way only will the mathematical training conduce to practical value in after life."

"Certain things up to and including at least the first year of calculus seem to me essential beyond question, and with the present trend of most theoretical engineering work, I should be inclined to put vector analysis in the same category, provided the course is one designed for engineers and not for pure mathematicians."

"The 'direction of natural forces to the benefit of mankind' —which is the engineer's function—is not a matter that rests primarily on mathematics. However, mathematical ability is certainly desirable and usually, but not always, indicates an engineering trend of mind."

"I have checked in both columns those subjects (Fourier's series and differential equations) which I consider as essential in some of their parts, but only as desirable in other parts, and which I therefore believe should be taught by special textbook devised for engineering use."

"It is my experience that the best engineers are not excellent mathematicians, but strong geometricians."

"This is exceedingly unfortunate, as it plainly shows that the men had been impressed more with the value of the mathematical study and mathematical training than with a good physical grasp of problems."

"I can look back over water power engineering practice since 1896 in the state, and can point out at least $25,000,000 lost because of similar lack of grasp of a purely physical problem without regard to the mathematics which were the measure of that problem. . . . Higher mathematics are very desirable for abstract investigation, but engineers are not investigators of that kind. . . . Higher mathematics have been the vehicle which has brought down to us the formula, and in ordinary engineering work, the engineer hasn't time to go back over the method by which these formulas were worked out."

The question of the time consumed by any subject not closely related to the practice of engineering must play an important part in the acceptance or rejection of that subject in an engineering course. There is, of course, much knowledge which is valuable for general culture, but which must be omitted in any educational plan for lack of time. This fact seems to be well recognized by those who advocated the omission of the higher branches of mathematics. The following quotations will illustrate this point: "All of the subjects you mentioned are, no doubt, valuable as mental training if one has time to devote to their study."

"A general knowledge of all of them is doubtless desirable for other engineering, provided he has time to master them, and provided he has the mental makeup which will enable him to study them easily and quickly.

"As the four years, or so, now given to a study of the profession by young engineers may be too short for a mastery of these studies, it is probable that it may be much more important to give a larger share of this time than is usual to gaining certain practical knowledge in which too many of our graduates are defective."

These and other opinions expressed in several personal interviews indicate that many engineers who have had both the mathematical training and the experience of successful practice are convinced that the engineering courses should offer

mathematics with greater emphasis upon the application to such problems as arise in the theory or practice of engineering, and less emphasis upon the pure mathematics in which the student of mathematics is interested.

There is no doubt that mathematics was once the only organized subject used for the purpose of bringing the student into contact with exact logical reasoning. The development of physics, mechanics, chemistry, and other sciences, however, now offers the student a means of realizing the necessity for carefully prepared data and seriously considered conclusions. These subjects also offer the advantage of having value and interest to him other than the mere training in power to draw such conclusions.

Hence these men feel that unless a given course in mathematics has a considerable offering of usefulness as a tool in the study of the theory or of the practice of engineering, it cannot be counted as an essential or desirable part of an engineering training. They would offer to the engineering student mathematics courses in which the emphasis is placed on the usefulness of the subject in the engineer's career, rather than on the mathematical theory involved; and expect from such courses together with the physics, mechanics, and other scientific courses, a sufficient training in the careful, logical reasoning which leads to reliable conclusions.

This leads us to one phase of the discussion which we have not yet considered; *i. e.*, the question of the amount of mathematical training necessary for the engineer who wishes to keep thoroughly abreast of the times by reading the literature produced by those who are carrying forward the development of the science of engineering. Although an engineer may never have occasion to use calculus in his every day practice, he may often wish to read the results obtained by others who have made valuable contributions to the theoretical side of his profession.

It is the testimony of those who were interviwed on this point that calculus including differential equations is desir-

able for the purpose of such reading. This was expressed as follows by one engineer: "If the engineer keeps alive his knowledge of mathematics as he should by occasional use, the training which he receives from a year of calculus should enable him to read such literature as he needs to keep up with the important developments in his profession." Such testimony strengthens the conclusion reached above that the average engineer is well equipped with mathematics when he has completed a year of calculus.

It should be understood that no objection can possibly be made to the unlimited opportunity for the study of the higher branches of mathematics, which could be accomplished by offering these branches as electives. There are indeed many engineers whose interest lies in research and the theoretical side of the profession. For such men, the extended study of all the mathematics which has any bearing upon the present or probable future development of engineering theory is of course highly desirable. Men like Steinmetz, Reynolds, and Stodola could never have accomplished their work without much knowledge of these higher branches. The course in an engineering school should, however, be planned for the great majority of the profession and not for an exceptional genius who shall carry forward the development of theoretical engineering. Indeed, such men are themselves most emphatic in the opinion that even the higher branches should be taught "by special textbook designed for engineering use."

It would seem, then, that in the minds of those interviewed on this point there is the conviction that even for those who find themselves interested in the more theoretical parts of the profession, the mathematics offered should strongly emphasize its application to the subject of engineering. The professional engineer needs to be well enough acquainted with mathematical subjects to know when to call in an expert mathematician. The engineer who is engaged in the research work which leads to new developments of the subject needs enough knowledge of mathematics

to interpret his thoughts and discoveries in these new fields. He needs to analyze these interpretations mathematically, because mathematics is the most convenient form of short hand for him to use when examining and manipulating the facts which are before him. His interest, however, is not, even here, in the mathematical process involved, but in the result obtained by the use of that process; hence, the contention that even the higher branches of mathematics should be taught to these men more largely through the medium of problems involving the subject matter in which they are primarily interested.

The question whether such textbooks can be produced, and by whom they shall be prepared is, of course, not within the scope of this investigation. It is evident, however, that in order to teach these subjects in the manner proposed, instructors must be obtained who have both the mathematical and the engineering ability necessary for such a comprehensive task. Those engineers who have sufficient knowledge of engineering practice with a thorough knowledge of the mathematics involved, can seldom be induced to leave the engineering profession for the teaching profession. For this reason, there is much testimony to the effect that the teaching of mathematics to engineers has been placed either in the hands of the pure mathematician who has neither knowledge nor interest in the engineering practice, or in the hands of an engineer poorly equipped with mathematical knowledge.

There seems to be no doubt in the minds of those who expressed opinions on this point, that the pure mathematician is the one to be preferred as a teacher of engineering mathematics. They deplore the fact that this choice is necessary, however, and greatly desire a change of conditions which shall make it possible to produce instructors whose sympathies and training will enable them to combine the two somewhat antagonistic spirits of pure mathematics and engineering practice.

The conclusions which have been drawn from the corre-

spondence and personal interviews with these engineers are quite similar in many particulars to opinions which were expressed in 1907 at a joint session of the American Society for the Advancement of Science. The speakers at this meeting included both practicing engineers and professors of mathematics in engineering colleges. The addresses were largely expressions of opinions rather than the results of extended investigations, but these opinions were strikingly in accord with the conclusions which have here been drawn from a canvass of the opinions of many engineers. The addresses given at this joint session have been published in the form of a symposium on mathematics for engineering students issued as a reprint from several numbers of *Science*.*

A very comprehensive summary of the opinions expressed in this symposium is given in the following paragraphs from a review by Professor H. W. Tyler: "Of the three engineers (who spoke at this meeting), one received his mathematical training abroad and naturally expressed himself with some reserve in regard to American conditions, but looks forward to the time when only applied mathematics will be taught in college, all necessary abstract mathematics forming a part of the entrance requirements. The other two dwell on unsatisfactory elements in existing conditions, and on results to be sought, both of them emphasizing the importance of skill in the use of mathematics as a tool."

"The further criticism of the engineers and of the professors of engineering, while varying widely in details, seems to connect itself with the general notion that mathematics is habitually presented to engineering students in too abstract form, with too little appreciation of the uses to be made of mathematics in engineering work."

There seems, then, to be a decided opinion among both professors of engineering and professional engineers, that, beyond a certain amount of elementary mathematics, which would probably include arithmetic, algebra, plane and solid

* July 17, 24, 31; Aug. 7, 28; Sept. 4; Oct. 2, 30–1908.

geometry, and trigonometry, the mathematics offered to engineering students should be taught with more emphasis on the applications of the subject to engineering problems. The pure mathematician, however, believes that there is a training quality to be obtained from the study of abstract mathematics which will be lost if the subject is taught through the study of its applications to any other science or profession. The mathematician believes that "Mathematics is a basal science and not a tool. The spirit of mathematics is of more value to the engineer than the particular things which can be accomplished. The engineer need not be a mathematician, but he needs to think mathematically; and to my mind, he needs the power of mathematical thought more than skill in manipulating a few mathematical tools in mechanical fashion."

In this connection, it is evident that the time element must be taken into consideration. One professor of mathematics says, "It is possible that better results could be obtained if the mathematical department had more time, say for a course in applications of mathematics to miscellaneous problems. But, as a rule, in our technical schools, the department of mathematics is allowed barely time to teach the necessary technique, with what illustrations and applications can be squeezed in. Hence, the mathematical department delivers to the engineering department an unfinished product; and it is the engineer's duty to teach the student to use the mathematics he has learned. Unfortunately, the professor of engineering is a poor mathematician and avoids this duty."

At this point, it seems to us, we have the suggestion of a possible remedy for the condition complained of by the engineers,—a course given by a thoroughly trained mathematician who has sufficient knowledge and sympathy for the engineering profession to be able to illustrate all the mathematical theory by problems drawn from the engineering field. Such a course must be allowed a much greater time than that now allotted to the pure mathematics course which does not stop to take up applications; but if this kind of training is desir-

able for the engineering student, certainly, time should be found to give it.

It is not the purpose of this investigation, however, to formulate the remedies for the undesirable conditions. It is sufficient for our purposes to set forth those conditions in definite form, and to formulate the opinions expressed in the data presented by those who are in touch with the undesirable conditions. These opinions may be set forth in four distinct conclusions:

First, from the standpoint of the engineer, abstract mathematics divorced from its applications is not desirable in branches beyond trigonometry, *i. e.*, mathematics beyond trigonometry is, for the engineering student, a tool and not a desirable end in itself.

Second, these subjects being desirable as tools, the training in the elementary mathematics through trigonometry should be more thorough in order to enable the student easily to manipulate such parts of the higher branches as he may need in his profession.

Third, study of theoretical mathematics beyond a year of calculus is not only undesirable, but is an actual hindrance to the practicing engineer in adjusting himself to the relative values of the physical and mathematical sides of the problems which arise in practice. Hence, more emphasis on the applications of mathematics to physical problems should be given in mathematical courses for engineers.

Fourth, such exceptional students as become interested in the theoretical side of the profession should be given ample opportunity, when that interest appears, to extend their mathematical training in whatever line may seem desirable for the particular branch of the profession in which they may desire to perfect themselves.

THE ENGLISH DEPARTMENT AND THE PROFESSIONAL SCHOOLS.

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Whatever may have been the evils resulting from the recent tendency of legislative committees, boards of trustees, and other bodies with permanent or temporary powers to probe into the organization and operation of our universities, one good has certainly resulted—the schools and departments of the university subjected in each case to the investigation have been brought more closely together and have been obliged, for the time being, at least, to forget their individual jealousies and animosities that they might present a united front to their critics without. As a professor of law at the University of Wisconsin put it after the recent "legislative survey" of that institution, "we have all been united in the one absorbing task of preparing statistics." From my own coign of vantage on a registration committee of the college of letters and science at Wisconsin I have observed that there was during the registration period last September far less elbowing for the desirable hours on the time table and far less scrambling for student elections than in previous years. All of this means that although certain departments may still feel that their existence depends upon a constant competition with their bigger and more successful neighbors, the majority are showing a tendency to become less departmental and more universal in their aims, and are recognizing the fact that however methods of instruction may differ, departments should unite in an effort to send from the university each June a group of students who are able to hold their positions in any community as college educated men and women.

In this broader conception of the aims of departmental effort the English department must, I think, have a prominent share. Up to the present the department has been concerned very largely with two groups of students, first, the freshmen of the required freshman English course, and, second, letters and science students, mostly women, who elect advanced courses in English usually with the view of teaching the subject. The idea that the department has any especial duty to perform beyond the freshman year for the large groups of students in the professional schools of the university has not so far seriously troubled the conscience of the English instructor. And yet there is very unmistakable evidence at present that the tendency in the engineering and agricultural colleges is away from the very highly specialized courses and in the direction of more elections in liberalizing subjects, and this widening of educational aims must be met by the English department, the only department which offers work sufficiently flexible and varied in content, and free from the obvious handicap which will prevent the foreign language departments from satisfying the desire of the professional student for a short course in a humane study. The frank acceptance by the department of this new obligation will result, I feel certain, not only in decided benefits to the professional students but also in a counter benefit to the department, in that it will introduce a new type of serious student and will broaden the aims of instruction in English.

The English department has never relished the accusation of superciliousness which some of its friends of the professional schools have implicitly brought against it. And yet in our attitude toward the engineering and agricultural colleges can we be entirely absolved of the charge? Haven't we after all just a trace of academic Pharisaism, a feeling down in our hearts that we cultured ones are a little better than these hewers of wood and drawers of water, who must needs exist, but with whom the less we have to do the better? Aren't we tolerably certain that Keats and cows and Carlyle

and carburetors can not by any possibility have a common denominator, and that the "engineer" who desires a course in Shakspere or the "agric" who has the temerity to tackle Browning are to be welcomed, perhaps, but regarded either as possible proselytes to our faith or as students not worthy of serious attention? The demand for the engineering and agricultural sections in freshman English at Wisconsin has never been a very insistent one. On the contrary, there is in the freshman English filing case a request from one of the older instructors in the department for "all morning sections and no engineers or agrics, please," and this request is, I think, an expression of desire only slightly franker than most English instructors would be willing to make. I have been giving for a number of years a special course for engineers; this semester I begin work with my fourth associate; they all entered the course only at the request of the chairman of the department, and the first three left after a single semester of service and as soon as there was an opportunity to return to "pure letters and science" work. In these cases the technical nature of the work undoubtedly had much to do with the instructor's desire to read themes less difficult, but beyond that lies the fundamental and perhaps natural predilection in favor of work with letters and science students.

The English department is not, of course, entirely to blame for this state of affairs; the professional schools have until recently hardly shown any tendency to come half way toward the establishment of closer relationships. The reasons for this are not hard to seek. When the professional schools were young—and their establishment is, after all, of very recent date—it was quite natural for them to introduce at once courses which were "practical." The impetus for this trend away from the "useless" and "antiquated" academic studies came from several sources, from the general demands of society for trained workers, from the specific demands of "self-made" employers of young graduates, from college teachers burning with eagerness to introduce courses in the

special subjects which they had studied for years, and lastly from students filled with commercial aims and with the ambition to secure from a minimum expenditure of time and money a fund of professional knowledge which could be immediately cashed in. In spite, then, of the more far-sighted educational policies of liberally educated men like Johnson, Thurston, Bailey, and others, the tendency to make of the engineering students skilled mechanics rather than broad-minded engineers, and of the agricultural students intelligent farm-laborers, rather than intellectually alert scientific farmers, continued. And naturally the breach between technical schools and the liberal arts colleges widened. In one of the largest universities of the east, the separation between engineering and agricultural courses and the arts course was until recently so complete that no work in English whatever was required of the engineering students, and it was seldom indeed that either "agric" or engineer disturbed the sacred precincts of the Hall of Humanities. In some other universities an introductory course in English has been required of all students in professional courses; beyond that, however, the English department has seldom concerned itself with the problem of regenerating the lost ones.

But there are at present unmistakable indications of a reaction against over-specialized technical curricula. Most of the evidence which I offer in support of this statement I have gathered from a contact of several years with a college of engineering. As far as I have yet discovered, however, similar conditions prevail in colleges of agriculture. In engineering education the value of liberal studies, the doctrine preached years ago by a few, is becoming more universally recognized not only by employers and teachers of engineering students but, much less decidedly, of course, by the maturer engineering students themselves. The value to the engineer of the study of English is one of the most persistent notes in the Publications of the Society for the Promotion of Engineering Education, and the index in *Addresses to Engineering Stu-*

dents, collected and edited some few years ago by Messrs. Waddell and Harrington, well-known consulting engineers, contains twenty definite references to English, twice as many as are given to the fundamental engineering subject of mathematics. The indication here that engineers and teachers of engineering students recognize the value of studies which lie outside of the special curricula of the engineering colleges is borne out by further evidence. A special investigator of engineering instruction in America informed me only a few months ago that the almost universal sentiment in engineering schools was for a broadening of the course; in support of this statement he had over fourteen hundred letters from practicing engineers, editors of technical magazines, and teachers in engineering colleges in all parts of the country. I have in my own letter files a modest collection of some two dozen letters from consulting engineers and editors, which, although they were not written in reply to a specific request for judgments on problems of engineering education, occasionally do contain such opinions. The following excerpt is from a letter written by the editor of one of the best-known engineering magazines:

"In my opinion," he writes, "the great weakness of technical education in this country has been the neglect of the fact that technical knowledge is only part of the equipment an engineer should have for his career in life; for success will very largely depend upon the human relations which he establishes, and particularly the relations with broad men of affairs upon whom his income will depend. One who can only talk technics and only write 'engineering English' is at a great disadvantage compared with the man of technical knowledge who is also an educated man in the sense in which the world at large understands that term."

The idea here expressed by an engineer not directly concerned with the education of engineering students is reiterated in more detail by an assistant professor of structural engineering at the University of Illinois in the *Engineering News*

for December 23, 1915. After pointing out what he calls the menace of overspecialization, this writer concludes as follows:

"An engineer in the broader sense is a man who can conceive a project, have it financed, and then organize an army of workmen to carry it out. One of these three functions is as important as another. The graduate who will develop into this type of man is what our engineering schools should produce. He is more likely to be produced by a broad training in science, art, and literature than by a narrow specialized training in technical subjects.

"A school should be interested in the career of its alumni fifteen or twenty years after graduation rather than in a meteoric success during the first year or two. This fact is becoming more and more realized; eventually it will predominate. When that time comes, the courses of study in the universities, which originally included only pure science, literature, and philosophy, which were later flooded with manual training, and which now are made up largely of highly specialized subjects, will then return to almost their original state. They will, however, contain a more constructive knowledge of literature and a greater wealth of science. Moreover, instead of the application of the sciences to the problems of engineering, the principles governing the application of the sciences will be emphasized."

It might be supposed that most of such expressions of opinion would come from men who are eager to have professional students elect the more "practical" of the courses in letters and science. This is by no means the case. While recognizing, to take a specific example, the immediate practical value of a course in the composition of technical papers, professional men usually believe that a general course in English composition which will bring the student into vital contact with subjects and forms of expression remote from his technical studies will serve much the same purpose as the more specialized course and will at the same time broaden his views. "The problem of English for engineers," writes one

of my correspondents, "is not that of teaching 'engineering English' but of giving the engineering students the same course which is given to the academic students."

It is not, of course, to be expected that the trend in the direction of a more liberal course will be exhibited to any great extent by the professional students themselves. The average undergraduate has about as much concern with the process of his intellectual development as the average healthy youngster of eight or ten has with his physical growth. Looking backward he sees, once the glamor of his high-school days are over, little behind the date of his matriculation in college; looking forward he sees little beyond the June of his graduation, to him a conclusion and not a commencement; and what lies beyond the horizon of his college life is dim, shadowy, and terrifyingly uncertain. If left to his own devices, he will choose those subjects which seem to lead most directly to a professional career the depths of which he has never sounded, and he is very likely to question the value of courses the immediate application of which he cannot understand. Freshmen in professional courses are almost invariably, and quite naturally, most interested in those subjects which seem to them most professional. "My favorite study," wrote a little Chinese freshman in one of my agricultural sections in English 1, "is the *animal husband,*" and I presume that "the animal husband" continued to be his favorite study until years later he learned the value of courses less patently connected with farming. The juniors and the seniors begin to count up the returns which the underclass courses are bringing them. Whereas the underclassmen are likely to glory in the clannishness of the professional school to which they proudly belong, the upperclassmen are more and more showing an inclination to spread out into more liberal fields. The dean of the college of agriculture at Wisconsin recently showed me a record of all juniors and seniors electing courses in letters and sciences. Upperclassmen, he said, are advised to choose their electives outside of the college of agri-

culture, and the number who do so is increasing yearly. An evidence of the interest in liberal studies among engineering students came to my attention a year ago when I was invited to speak before the civil engineering fraternity at Wisconsin on the relation of English and engineering. At this time I made the significant discovery that this fraternity, under the direction of a committee of senior engineering students, was making a practice of inviting members of the letters and science faculty in on Sunday afternoons to address them on philosophy, literature, and other subjects often quite remote from their professional interests. Engineering and agricultural students who elect courses in letters and science subjects are by no means the least promising members of a class. I have at present in my elective course in sophomore composition three professional school students, a senior engineer, one of the most substantial members of the class, a junior "agric," without doubt my most eager student, and a sophomore engineer, older than the average undergraduate and a bit of a philosopher. Every one of these students has done good, steady, solid work. Last year one of the best students out of a couple of hundred in the introductory course in English literature was a senior engineer.

If, then, the trend of technical education is in the direction of more work in liberal subjects, how can the English department of the large university, where the colleges exist side by side, share in this movement? What returns, moreover, can the English department expect from the added responsibility of assisting the professional school students to broaden their course of study? My answer to the first question is that the English department can take a part in the movement by meeting the professional schools half way, by increasing in every way possible the contact between academic and professional students and academic and professional instructors, and by giving definite liberal elective courses, primarily in composition, to students in professional colleges. My answer to the second question is that by such an effort the English depart-

ment will gain immensely by broadening the aims of its instruction and by bringing into direct contact with the department a new and highly desirable type of student. The specific suggestions which follow are based upon an analysis of the conditions existing at the University of Wisconsin; it is believed, however, that these conditions are typical of those in most of the large state universities.

Definite contact between academic instructors and students and professional school students can be made in a number of ways. In the first place, I do not believe that there should be any such things as "engineering sections" and "agricultural sections" in the required freshman English course. Within the last three years the college of agriculture at Wisconsin has very wisely, I think, arranged with the department of English for mixed classes of agricultural and letters and science students. The spirit of this arrangement was defeated last year by one English instructor who in transferring students from his section deliberately culled out all of the agricultural students in his class, and this year by another instructor who tried by an automatic arrangement to exclude all agricultural students, in spite of the fact that his section came at an hour which was most convenient for them. The "engineering sections" at Wisconsin still exist, but it is expected that the administrative reasons which have prolonged their existence will soon give way to broader issues.

Individual instructors in English can do much to increase the contact. In the mixed classes of academic and professional school students the "agric" and the "engineer" can be led to lay their opinions on questions of general interest by the side of those of the academic student. In conference the instructor can do wonders in breaking through the crust of narrow interests and giving the professional school student a broader vision. On the campus, in the boarding-houses, everywhere, in fact, the wide-awake instructor can pursue his mission. Too much of our contact with students is in the formal atmosphere of the class-room, and not nearly enough in the

informal atmosphere of the campus. I am certain that some of the best things I have done for my students have come in the few minutes' chat on a walk down the hill, or in the minutes snatched between classes. And the professional school upperclassmen are by no means as unresponsive to this approach, and by no means so uninterested in liberal subjects as many instructors imagine them to be. If the interest of the freshman is luke-warm, that of the senior is often eager. Last year, for example, I had fully as many requests from upperclassmen among the engineering students for copies of the list of recommended readings published by the English department as I had from academic students, and this in spite of the fact that most of my students were registered in letters and science.

But in addition to employing these general methods for increasing the contact of the college of letters and science and the professional colleges, the English department should, I believe, provide definite courses likely to attract students from other colleges. The freshman English course required of all professional school students is not sufficient. Very much, if not most, of the discipline which it provides must of necessity be drill work designed specifically to overcome positive illiteracies, and even in the second semester when the work may be broadened in scope, much of it must still be corrective. Moreover, freshmen in professional courses are not as receptive to liberalizing study as are the seniors. As has been indicated, they are narrow in point of view and regard with suspicious jealousy any encroachments upon their "practical" studies. They fear the Greeks who bear gifts. It would be a difficult task for any English instructor to beat in the Philistinism of a commerce freshman of mine who wrote, "I am taking the commerce course so that when I get out, I can look the other fellow straight in the eye and *do him on a strictly legitimate business proposition.*" Three years of college might make such a student receptive to higher views; for this particular student the executive committee decided that one

year of college life was enough. Another handicap under which freshman English suffers is that it must of necessity be given in the first year of the college course. The freshman's horizon, as has been pointed out, is bounded by the June of his graduation, and his interests have not yet extended to the point at which he comes to have a vital interest in things bigger than his college affairs. The senior, however, realizes that the time of his departure into the great world beyond his graduation is painfully close, and he is beginning already to see the limitations of his college course as a genuine preparation for life. It is the senior in the professional schools, then, who will reap the greatest good from a contact with English as a liberal study.

To substitute a required senior course for professional students for the freshman English course would not, however, be wise. No liberal English course for seniors such as I have in mind could be given excepting to students who had received the corrective drill which it is the aim of freshman English to provide. The idea which sometimes prevails that mere residence for three years in a university community will result by a process of intellectual absorption in students' writing correctly is quite fallacious. I have had the opportunity this year of teaching side by side a section of freshman English composed of freshman engineers and a section of freshman English composed of junior engineers who have had up to the present no university work in English. I have not found that these juniors write any more correctly than the freshmen; if anything, the freshmen have brought from their high-school courses in English a knowledge of details which the juniors have for the most part forgotten. And outside the freshman English course students are not likely to learn correctness of expression. Aside from themes the underclassman in the professional colleges does very little writing until his junior year. He claims, moreover, that he has very little time for good reading. And the correctness of expression

which he is likely to learn on the campus almost any bit of student dialogue will show to be very slight.

The advanced courses in English composition which aim to provide "practical" instruction for students in professional colleges bear, of course, no relation to liberal work in English. The course in the composition of technical papers consists of a study of the principles of expository writing as these affect the composition of technical descriptions, expositions of processes, reports, etc. The course in commercial correspondence consists of a study of the best business letter forms and of the psychology of business relations. Neither course aims to be liberal. The general course in advanced composition for letters and science sophomores attracts some students from the professional colleges; the work is not, however, adapted to their needs, and the make-up of the class is, moreover, so heterogeneous as to render difficult any unity of instructional aim. Some of the students are young women who are taking the work because it is a part of their requirement for a teachers' certificate; others have been dragooned into the course because of poor work in freshman English. It is obvious that the points of view of these students vary. Moreover, at least half of the students in the class are sophomores who have not yet obtained the broad view of their studies which many of the seniors have come to possess.

The liberal English course for seniors in professional colleges which I have in mind can best be understood, I think, from an explanation of its aims. In the first place, it would be primarily a composition course. I do not believe that the time has yet come when the men students from professional colleges will flock in any great numbers even to general courses in literature. A special introductory course in English literature offered at Wisconsin this year by one of the most popular lecturers in the expectation of attracting students from the professional colleges has an enrollment of only seventeen; of this number only five are engineering students, and there are no students from the college of agriculture.

The proportion of women to men in eighteen literature courses beyond the prerequisite general course is about five to one; in the advanced courses in composition, on the other hand, the number of women and of men is about equal. It does not follow, moreover, that a course primarily in composition could not bring the students into an incidental but none the less vital contact with literature; a reading of Ruskin, and Carlyle, and Pater, and Emerson, and even of Browning, and Tennyson, and Meredith, and Swinburne might very well be a part of the intellectual discipline which an advanced course in composition would aim to give.

The course which I have in mind would aim specifically to teach students to *think straight* rather than to write correctly. Mere correctness of expression is the primary aim of the first semester's drill in freshman English; it would, therefore, be incidental in an advanced course. A liberal course in English composition for seniors in the professional schools should aim to stimulate rather than to impart bare facts. Throughout the three years of his college life the professional school senior has been pumped full of facts—facts about electricity, facts about gas-engines, facts about cows and sheep and fruit and grain. Even in his liberal studies, his languages, his political economy, and his freshman English, the emphasis has been largely upon facts. What he has not received in any definite measure is the ability in connection with abstract ideas to separate fact from theory, to weigh evidence, to recognize authority, to coördinate diverse elements, and to generalize safely, to grip, in other words, with any real mental vigor, once outside his world of facts, great questions of human interest. And yet this demand upon his intellect is absolutely certain to be made as soon as he leaves college. At no time since the Civil War has the need in America been greater for men who can think clearly and sanely on questions quite remote from those which concern them in the pursuit of their vocations. Too many men shirk the task of thinking deeply for themselves; through mental inertia and

lack of mental discipline they do their thinking vicariously, living in the quotation marks of some editor or pamphleteer. The course for seniors which I have in mind would aim to create in the students the habit of facing questions courageously and thinking them through independently, deliberately, dispassionately.

A further result which such a course should accomplish is the stimulation to a broader view and a wider interest in all problems of humanity. Recent tests in a number of eastern colleges seem to indicate that the average student is densely ignorant of what is going on in the world; and educators point to the results with sarcastic comments on the narrowness of interest of the modern college student. Now it seems to me that in so far as these test questions are worth answering at all, the failure to answer them is as much of an indictment of the college as it is of the student. What effort has the college really made to induce the student to read widely and well? And if he does not get the stimulus to do so in college, where is he likely to get it? Unlike the earlier generation of students whose fathers were for the most part professional men, the modern students come very often from fathers who are tradesmen or craftsmen, ambitious for their children's education but unable to give them any vital contact with books at home. And these children we, who are teaching in the university by virtue of the fact that we were brought up to love the fun of reading, expect suddenly and without very much assistance to prefer the *Atlantic Monthly,* and the *Nation,* and the *New Republic* to the trashy magazines which offer no challenge to their intellectual powers. A liberal course in English composition such as I have in mind would aim to create a catholic interest in all human problems and to assist in making men who would not regard the *Atlantic Monthly* as "high-brow" and therefore beyond them, but who would see in it the valuable opinions of trained thinkers who have touched life from various angles. Such a course as I have in mind would train the student to read all articles in a

high-class magazine if not with equal understanding at least with equal intellectual eagerness.

It is not, naturally, to be supposed that the complete liberal education which I have outlined here can by any possibility be given to even the most eager student within the narrow limits of a single two-hour course. What can be done, however, even within such narrow bounds, is to awaken a latent intellectual thirst, perhaps, even, to create a new one, and almost certainly to give the receptive student a strong thrust in the direction of self-cultivation.

And what gains might the English department expect to reap from such efforts to increase the contact between the liberal arts college and the professional schools? I believe that two distinct returns might be expected, first, the addition to the department of a number of students of a new type, and, second, the broadening of instructional aims.

One of the most noticeable things in coeducational universities is the completeness with which the women students have monopolized the older humanities. It has been already pointed out in another connection that in the English department at Wisconsin the proportion of women to men in the literature courses which follow the "general survey" course is about five to one. Many classes are made up wholly of women. The teachers' course in English has at present an enrollment of forty-six women and four men. Out of thirty-six thesis students which I have had in the last four years only three have been men; of these one was majoring in football, one was a law student who was taking English "on the hill" as the line of least academic resistance, and the third was an odd will o' the wisp who sampled all courses and finished none. The gradual educational changes which have led to this state of affairs are, of course, known to everybody. In the break-up of the old liberal arts college into the multitude of little professional courses which it now virtually consists of, English, since it offers no professional attractions to men students, fell to the lot of the women, and has come to be regarded as a

women's course. I do not believe that even the women students regard with any high degree of favor the man who has the temerity, or, as is too often the case, the indolence, to major in English. I remember yet how my cheeks burned when my dancing-partner in an eastern university where I was studying English observed tartly, "If *I* were a man, I'd take something worth while." Now these conditions lie too deep to be greatly influenced by any single effort which the English department might make to change them. I cannot help feeling, however, that the introduction into the department of a number of men students from the professional schools will help to reëstablish the balance of things and to make the study of English more respected by the students of other colleges.

The broadening of instructional aims which has been spoken of as another gain likely to come to the department from an increased contact with the professional colleges will result, of course, from the circumstance that the professional school students who elect the liberal course described will have absolutely no professional interest in English. At present almost all elective courses in English are more or less filled with women who expect to teach English either as a first or as a second subject, and the English department finds itself, as has been said, engaged largely in the task of conducting a professional school. I often have a consciousness in my class in sophomore composition, and I do not believe that I am alone in this experience, of the presence of students who view the work of the course not as a liberalizing leaven for their intellectual loaf but as possible grist for their pedagogical mill. And it would be refreshing to face a class of seniors from the professional schools with a feeling that at last I was away from the indirect drilling of prospective teachers.

Finally, although the effects of such an effort to reach out as has been described would be slow, I believe that they would be certain and lasting, and that as a result of our endeavors

to give seniors in professional schools new intellectual contacts, we should be reaching into homes the children from which would have an eagerness for knowledge that we now miss in our students. And ultimately—is this too much of a vision?—the time might come when it would be unnecessary to demonstrate biennially to the legislature that the department of English has a right to exist by the side of the departments of poultry husbandry and structural engineering. The English department has been the rearward in the retreat of the humanities; in their return to a position of honor it may be in the van.

SOME SIMPLE DEMONSTRATION EXPERIMENTS IN THE ELEMENTARY PRESENTATION OF THE THEORY OF ELASTICITY.

BY W. S. FRANKLIN AND BARRY MACNUTT.

We believe that it is extremely important to develop clear ideas of internal stresses and strains in presenting the elementary theory of elasticity to students, and this paper has been prepared in order to give other teachers the advantage of our experience along this line.

When a rod is stretched or compressed or bent or twisted, each small spherical portion of the material of the rod is converted into an ellipsoid, and a clear picture of the distortion of a small portion of the rod may be obtained by considering that a material sphere is changed into an ellipsoid by elongating (or shortening) the material of the sphere uniformly in three mutually perpendicular directions. Therefore *the change of shape of any small portion of a distorted body consists of a lengthening or shortening of the small portion in each of three mutually perpendicular directions.* This is a proposition of fundamental importance in the theory of elasticity, and it may be established theoretically on the assumption that there are no cracks or ruptures in the distorted material.* It is sufficient, however, with a class of beginners to elucidate the proposition by means of the following experiment with a sheet of rubber.

Figure 1 represents a thin sheet of rubber on which are drawn a large circle and a number of small circles, and Fig. 2 shows the rubber sheet after it has been stretched in a complicated manner. *Each of the small circles has been changed into an ellipse,* but the large circle has not been changed into an elipse. The axes of each small ellipse show the directions in which each part of the rubber sheet has been

* See Franklin, MacNutt and Charles' *Calculus*, page 252.

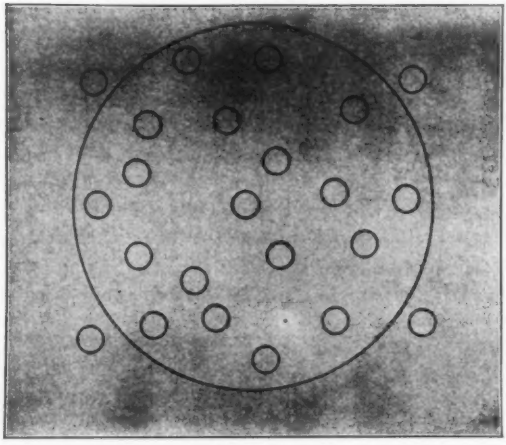


FIG. 1.

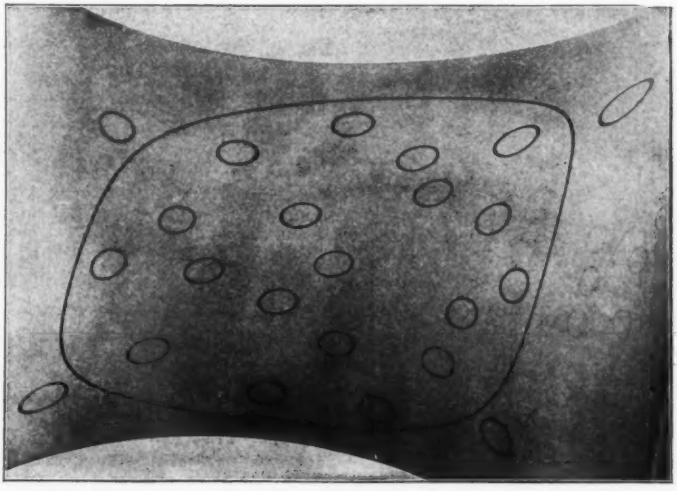


FIG. 2.

elongated (or shortened), and the amount of the elongation (or shortening) in the direction of each of the axes is shown by the length of the axis of the ellipse as compared with the diameter of the small circles in Fig. 1. It is evident that the different parts of the rubber sheet are not similarly distorted in Fig. 2 because the small ellipses are not similar and their axes are not parallel. Therefore, the distortion of the rubber sheet in Fig. 2 is said to be non-homogeneous. Fig. 3, however, shows each part of the rubber sheet similarly distorted because the small ellipses in Fig. 3 are all alike and their axes are parallel. Therefore, the distortion of the rubber sheet in

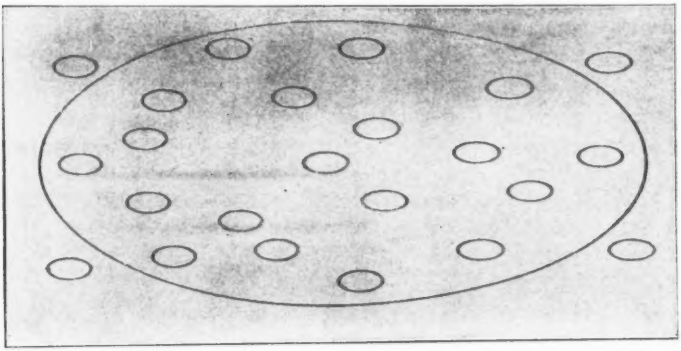


FIG. 3.

Fig. 3 is said to be *homogeneous*. In any homogeneous distortion a large part of the body is distorted in exactly the same way as each small part of the body. Thus the large circle in Fig. 1 is changed to an ellipse in Fig. 3 and this ellipse is similar to the small ellipses and its axes are parallel to the axes of the small ellipses. In a non-homogeneous distortion a large part of the body is not distorted in the same way as any small part of the body. Thus the large circle in Fig. 1 is changed to an irregular oval in Fig. 2.

It is a familiar fact that a circular disk of material is

changed to an elliptical disk by elongating (or shortening) the material of the disk in two mutually perpendicular directions, and therefore the distortion of each small part of the rubber sheet in Fig. 2 (and of course in Fig. 3 also) consists of an elongation or shortening of the material in two mutually perpendicular directions. In Fig. 2 each small part of the rubber sheet is rotated slightly in addition to its actual distortion. In Fig. 3 the small parts of the rubber sheet have not been rotated.

The ellipse, into which a small circular portion of the rubber sheet is converted by distortion, gives a clear geometrical picture of the distortion or strain of the small portion, and the axes of the ellipse are called the *axes of the strain*. Similarly, the ellipsoid, into which a small spherical portion of a distorted body is converted by distortion, gives a clear geometrical picture of the distortion or strain of the small portion, and the axes of the ellipsoid are called the *axes of the strain*.

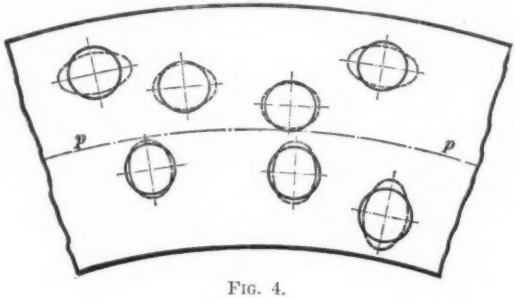


FIG. 4.

Longitudinal Strain.—When a long rod is lengthened (or shortened) we have what is called *longitudinal strain*. Every portion of the rod is lengthened (or shortened) in the direction of the axis of the rod, and shortened (or lengthened) in every direction at right angles to the axis. This is easily seen by stretching a rubber band, the band is reduced in thickness when it is increased in length.

The stretched rod is an example of homogeneous longitudinal strain, whereas a bent beam is an example of non-homogeneous

longitudinal strain. Thus Fig. 4 is a side view of a bent beam. The small circles represent small spherical portions of the undistorted beam, and the ellipses represent the ellipsoids into which these small spherical portions are converted by the bending. Each filament of material in the upper half of the beam is lengthened more or less, like a stretched rod, and each filament of material in the lower half of the beam is shortened more or less, like a rod subjected to endwise compression. Also, each filament of material in the upper half of the beam becomes smaller in diameter like a stretched rod, and each filament of material in the lower half of the beam becomes larger in diameter like a rod subjected to endwise compression. This lateral shrinkage of the material in the upper half of the bent beam, and lateral swelling of the material in the lower half of the bent beam changes the shape of the beam section as shown

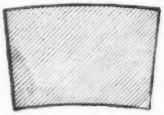


FIG. 5.

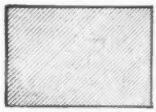


FIG. 6.

in Figs. 5 and 6. This change of shape of the section of a beam by bending can be shown by bending an ordinary rubber eraser of square section or by bending a large rectangular bar of molasses-and-glue composition such as is used for printers' ink rollers.

In the theory of the bent beam, as developed in all elementary treatises on the strength of materials, the lateral contraction (in the upper half of Fig. 4) and the lateral expansion (in the lower half of Fig. 4) are entirely ignored.

Shearing Strain.—A sheet of muslin is stretched over a square frame as shown in Fig. 7, and the frame is hinged at the corners so that it can be changed from a square to a rhombus as shown in Fig. 8. Several circles are drawn on the undistorted sheet of muslin, as shown in Fig. 7. Then when the sheet is distorted the circles are changed to similar ellipses with axes

parallel as shown in Fig. 8. The distortion is homogeneous; every portion of the muslin sheet is lengthened in the direction

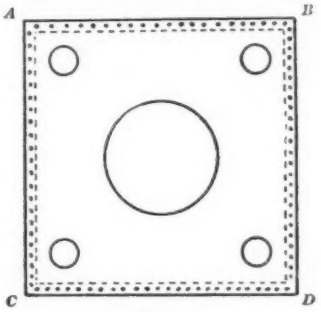


FIG. 7.

of the diagonal *BC* and shortened in the direction of the diagonal *AD*. Imagine the sheet of muslin to represent a thick slab of elastic material like rubber. Then the distortion or strain

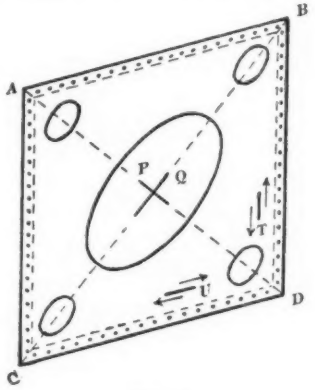


FIG. 8.

which is represented in Fig. 8 *without any change of thickness of the slab* is called *shearing strain.*

Force Actions Between Contiguous Parts of a Distorted Body.—The distortion of a body is called strain, and the strain at a point (the distortion of a small portion of the body surrounding the point) consists of three mutually perpendicular lengthenings or shortenings as explained above. The force action between continuous parts of a distorted body is called *stress,* and the stress at a point (the force action in a small

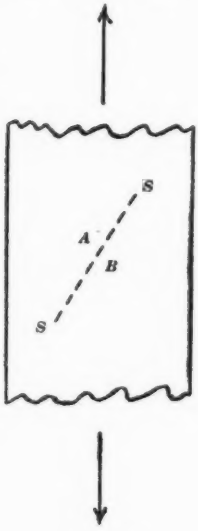


FIG. 9.

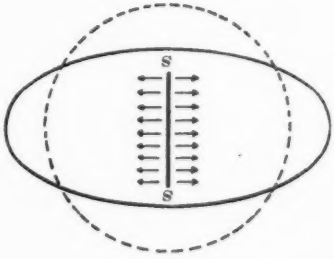


FIG. 10.

portion of the body surrounding the point) consists of three mutually perpendicular pulls or pushes as may be understood from the following discussion.

Consider a portion of a body which is distorted in any manner whatever. For example, Fig. 9 represents a portion of a stretched rod. Consider a small plane area *SS* in any direction, and let us call this plane area a *section* for brevity. The portions of material *A* and *B* on the two sides of the sec-

tion *SS* exert a force action on each other across the section, and this force action across the section divided by the area of the section (that is, the force action per unit area of section) is called the *stress on the section.* When the force action across the section is perpendicular to the section we have what is called a *normal stress on the section,* a simple push or pull as it is called in the following discussion. When the force action across the section is parallel to the section (the materials *A* and *B* tending to slide over each other) we have what is called a *tangential stress on the section.*

The dotted circle in Fig. 10 represents a small spherical portion of a body, and the ellipse represents the ellipsoid into which this small spherical portion of the body is changed when the body is distorted. It is evident from considerations of symmetry (the substance being assumed to be isotropic) that the force action across the section *SS* must be normal to *SS,* that is, the stress on *SS* must be a simple push or a simple pull; and what is here stated is true of any section at right angles to any one of the three principle axes of the ellipsoid into which a small spherical portion of a solid is converted by strain. Therefore, *the force action between the contiguous parts of a distorted body always consists of three simple pulls (or pushes) at right angles to each other.**

It is not worth while here to establish the general equations expressing the relation between stress and strain for an isotropic substance showing that the four well known elastic constants, stretch modulus, bulk modulus, slide modulus, and Poisson's ratio, are all expressible in terms of two fundamental constants for any given isotropic substance.† It is worth while, however, for the sake of the following discussion to

* This proposition is here derived for an isotropic substance. The proposition is true, however, for any homogeneous substance, isotropic or not; and its general proof rests upon the conditions of equilibrium of a small cubical portion of the substance under the forces exerted upon it by the surrounding material. See article *Elasticity, theory of* in *Encyclopedia Britannica,* 9th edition.

† See Franklin and MacNutt's *Mechanics and Heat,* pages 213–218.

point out the character of the stress which accompanies a shearing strain. Consider the shearing strain which is represented in Fig. 8. There is a simple pull of, say, S pounds per square inch across the section P which is at right angles to the line CB; there is a simple push of the same value across the section Q which is at right angles to the line AD; there is a tangential stress of the same value across the section T which is at right angles to AB or CD; and there is a tangential stress of the same value across the section U which it at right angles to AC or BD.‡

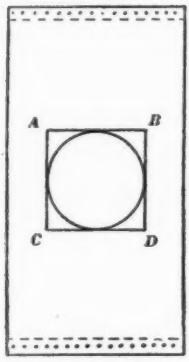


FIG. 11.

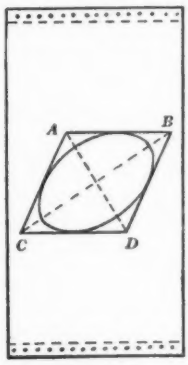


FIG. 12.

Stresses and Strains in a Twisted Rod.—The strains in a twisted rod may be clearly represented by means of the arrangement shown in Figs. 11 and 12. A large cylinder of sheet metal has a pivoted wooden disk at one end and a fixed wooden disk at the other end; and muslin cloth is wrapped around the cylinder, sewed together and tacked to the end disks. When the pivoted end disk is turned the sheet of muslin is distorted like the material in a thin cylindrical shell of a twisted rod. Figure 11 shows a circle and a square drawn on the undis-

‡ This matter is fully discussed on pages 207–209 of Franklin and MacNutt's *Mechanics and Heat.*

torted muslin sheet, and Fig. 12 shows the circle changed into an ellipse and the square changed into a rhombus by the twist. Every portion of the cloth is lengthened along lines running around the cylinder parallel to *CB*, and every portion of the cloth is shortened along lines running around the cylinder parallel to *AD*.

The cloth in Fig. 12 represents a thin cylindrical shell of the material of a twisted rod, and the stresses in this thin cylindrical shell may be understood with the help of Fig. 13. A simple pull of, say, *S* pounds per square inch acts across every section like *P*, a simple push of the same value acts

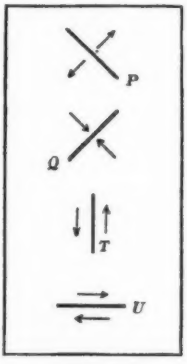


FIG. 13.

FIG. 14.

across every section like *Q*, a tangential stress of the same value acts across every section like *T*, and a tangential stress of the same value acts across every section like *U*. There is no force action across a section which lies in the surface of the cloth (at right angles to a radius of the cylinder). Compare Figs. 12 and 13 with Fig. 8.

A further help in the building up of a clear understanding of the stresses in a twisted rod is to use three similar tubes of

elastic material as shown in Figs. 14, 15 and 16. The tube in Fig. 14 is whole. The tube in Fig. 15 is slotted along a helical line parallel to *CB* in Fig. 12. And the tube in Fig. 16 is slotted straight along one side. The tube in Fig. 14 is strong in resisting twist. The tube in Fig. 15 is easily twisted in the

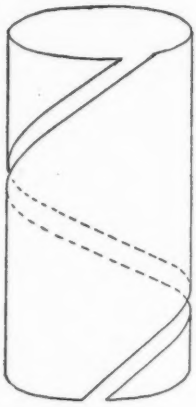


FIG. 15.

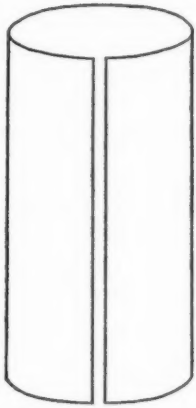


FIG. 16.

direction which widens the slot because this direction of twist tends to produce a simple pull across the slot, and strong in resisting a twist in the other direction because this direction of twist develops a simple push across the slot. The tube in Fig. 16 is easily twisted in either direction because a twist in either tends to develop a tangential stress across the slot and causes the sides of the slot to slide over each other.

ENGINEERING ENGLISH AT MICHIGAN.

BY J. RALEIGH NELSON,

Assistant Professor of English, University of Michigan.

The fact that engineering students respond with intelligence and enthusiasm to the appeal of English courses, when the work is so shaped as to meet their special needs and to rouse their peculiar interests, is well illustrated by the development of the English curriculum in the colleges of engineering and architecture at the University of Michigan during the past four years. Four years ago, there were enrolled in English 516 students, most of them taking merely the regular freshman theme courses. The present year the enrollment has reached a number more than double that of four years ago. At the beginning of this period, in the first semester of 1912–1913, only thirty-two students were taking any English courses not required for graduation; in the last semester of this four-year period, there were enrolled in the elective courses in English 526 students—an increase of over one thousand per cent. The enrollment for these four years was as follows:

Year.	Required Work.	Electives.	Total.
1912–1913:			
First semester	224	32	256
Second semester	143	117	260
Total	367	149	516
1913–1914:			
First semester	289	167	456
Second semester	180	230	410
Total	469	397	866
1914–1915:			
First semester	264	220	484
Second semester	155	376	531
Total	419	596	1015

1915–1916:			
First semester	278	272	550
Second semester	123	526	649
Total	401	798	1199

This phenomenal growth in the number of students taking English has been due, in the first place, to the types of elective courses offered. These have proved especially attractive to the students of engineering and architecture because they have appealed to their particular interests and have provided for their particular needs. Appreciating the fact that such students are naturally interested in their contemporaries and that in so far as they have any literary attractions, it is for the short story, the current novel, and the latest play, the English faculty has accordingly formulated courses in the short story, the modern novel, the modern drama, and in various aspects of current literature. These courses aim to take advantage of the student's natural interest in these literary forms and to stimulate him to read with spontaneity and enthusiasm what he feels real pleasure in reading. By judicious direction and tactful discussion they aim also to develop in him some conscious standards of taste by which to judge the things he does read. He is inspired to read more discriminatingly and critically. It should be noted that the aim and purpose of these courses differentiates them absolutely from anything offered in the college of literature, science and the arts. They are made for our own students, and as such they do the work.

But while on the one side there has been developed a group of reading courses appealing to the student's special predilections and aiming to develop a more critical taste, there have been worked out in the other direction a large number of elective courses which are frankly practical, and which aim definitely to equip the student for his technical work. These include courses in business English, technical journalism, technical papers, report-writing, note-taking, and public speaking for engineers. In all this work, every effort is made

to correlate the English with the work the student is doing in his technical courses. He is urged to use material that is of real value to him as an engineering student, and he is especially encouraged to present the results of any original research or of his own personal experience in any of the industries. This correlation of the English courses with the student's engineering work and the constant stimulus given him to express himself regarding the things he is interested in has done much to make the English courses justify themselves and appeal to the practical sense of the students.

The fact that such courses, appealing either to the student's natural love for contemporary literature or to his practical sense of his own needs, have been developed does not, however, wholly account for the increase of over one thousand per cent. in the enrollment in the elective courses. The very generous encouragement given this work by the dean and the heads of the various departments has gone far toward creating throughout the student body an impression that the English courses are profitable for one to take. There has gradually developed a tradition in the colleges of engineering and architecture that a man needs as much English training as possible if he is to get far in his profession. This feeling has been deepened also by the utterances of alumni and of practicing engineers writing for the technical magazines until we have at times hardly been able as a department to meet rapidly enough the increasing demand for English on the part of both students and faculty. The requirements in English have now been raised from five to six hours. The student, in addition to his freshman theme course, will take a two-hour writing course in the junior or senior year. As this requirement has not yet come into effect, it has not yet influenced our enrollment. During the next four years the present enrollment in English will, in consequence of this change, increase by at least one third.

There are certain features of this work which seem worthy of special mention. The personal consultation of the instruc-

tor with the student has always been an integral factor in the work of the English department. Instructors are required to give at least eight hours a week to this work, and to employ some system which shall bring students to their offices at regular intervals. Naturally the methods employed vary with the preference of the instructor. Some of the men appoint for each student a regular consultation period of ten minutes once in two weeks. Some prefer to devote the eight hours a week to the students who are in special need. These men excuse the A and B students from such consultation and appoint regular periods for C and D students only. Again, other instructors take their men in groups of three to six and spend the time with these groups in drill on common difficulties. The foreign students are given fifteen minutes apiece each week; the juniors and seniors often spend with the instructor thirty to fifty minutes on the preliminary work connected with each major assignment. Some of the most advanced students have received as much as two hours of consultation work on a single paper. Whatever the individual method, the department as a whole is united in its belief that this conference work is almost more essential to success than the recitation itself. The construction this last year of a sufficient number of offices so that each of our eight men has his own private office has made it possible to develop this conference work with some system.

Emphasis more and more in all these courses has been laid on the value of oral work. In English 1, the freshman theme course, at least one third, and in English 2, the sophomore writing course, at least one half of the time is given to the oral presentation to the class of material from the front of the room. In English 3, public speaking for engineers, the students are required to present more or less technical subjects demanding the use of various kinds of illustrative material. In English 5, the juniors and seniors are given a more formal course in the preparation and presentation of scientific and technical papers, in which attention is paid to

the presentation of papers requiring the use of illustrative material. In all this oral work the aim is to teach the student to speak effectively on his feet in the presence of a critical audience and to use such concrete materials as are needed in his particular type of subject for illustrative purposes. This feature of the work has proved most productive of results and has in addition been extremely popular.

Our department has the distinction of being one of the first in this country to offer special courses for foreign students. These courses deal simply and practically with the phonetics of English speech in a way which will serve to correct the difficulties of the individual student. They give also sufficient drill in reading aloud to aid the student to acquire a correct pronunciation and to enlarge his vocabulary. They give him practice in conversation of a sort to meet his immediate needs in the class room and in the life of the community about him. The student continues this special work until he can satisfy the English department as to his pronunciation, his written idiom, and his ability to take dictation with reasonable accuracy. When he is no longer hampered by his difficulties in English, he is required to take at least one of the regular composition courses offered for American students. This plan has seemed to produce very satisfactory results.

The four courses specially planned for juniors and seniors, which under the new rule will be required of all students in the engineering college for graduation, are English 5, scientific and technical papers, English 6, report-writing, and English 9 and 10, business English. As the first two of these courses deal with highly specialized types of exposition, emphasis is laid in both on the fundamentals which govern all expository writing. The special problems which arise in the preparation and presentation of scientific or technical material and in the drawing of reports differentiate the two courses somewhat sharply. In English 5, the most economical methods of accumulating and organizing scientific and technical material, the most appropriate use of illustrative

matter, the most effective handling of a variety of subjects before audiences of different sorts, form the bases for the shaping of the work. The student is required not merely to prepare his manuscript as if for actual publication, but to present his papers to the class as if to a real audience of a critical and professional sort.

In the report-writing, the major assignments are as largely as possible made by the professors in the engineering courses in which the student is engaged. The criticism of these professors is sought on the side of the technical material. Special attention is given to developing in the student a consistent method of approach to the task of report-writing, so that he may have a critical standard to apply not only to his own work but to the reports which he may have occasion to use in his reference work. The matter of form, which here becomes increasingly important, is duly emphasized, and the library of typical reports, accumulating through the generous interest of our alumni and friends, offers both instructor and students ample opportunity to make a careful study of the best usage in reports of various types.

In addition to the regular class work, the instructor in charge of these courses has put his time at the disposal of all students in the department engaged in research work who need help in shaping up their reports for final presentation. Students are also encouraged to write for publication and for competitive prizes. Several of our men have succeeded in doing work of this sort in a most creditable manner.

The two courses in business English have been the outgrowth of the old course in commercial correspondence. In Course 9, a study is made of advertising, general publicity, and commercial correspondence. In Course 10, general business, interviews, testimony, and sales are the special subjects of study. Both of these courses are based on the psychology and usage of business transactions. On this basis is worked out in a very practical way the study of a variety of business situations and the best way to handle them. The work con-

sists of lectures, assigned reading, and written exercises. In Course 9, the written work is chiefly business letters and advertising, while in Course 10 the written work consists of longer papers which require intensive study of business situations and a careful organization of material.

These four courses have been so carefully worked out during the past four years that by the fall of 1916, when they become a part of the six-hour requirement in English for all juniors and seniors in the college of engineering, they will be thoroughly established and the English department will be in a position to carry the rather difficult technical work with some facility.

The present curriculum in English in the colleges of engineering and architecture provides for twenty-two courses, fourteen of them being writing courses and eight of them being reading courses. They are grouped as follows:

A. Writing Courses:

1 and 2: General courses in oral and written exposition.
3 and 4: Courses in oral English.
5 and 6: Courses in technical English.
7 and 8: Technical journalism.
9 and 10: Business English.
16, 17, 18, 19: Courses for foreign students.

B. Reading Courses:

21: A general reading course.
22: The short story.
23 and 24: The novel.
25 and 26: The drama.
27 and 28: Scientific literature.

Every one of these courses has been formulated to meet an evident demand, and every one fits into a well-unified scheme. They are thus correlated, by a definite unity of purpose, to each other and to the life interests of the students for whom they are planned.

WHAT IS INDUSTRIAL ENGINEERING?

BY P. F. WALKER,

Dean, School of Engineering, University of Kansas.

An unfortunate tendency of the present period is to confuse industrial engineering and the science of management. Many writers of magazine articles and of books use the terms as though synonymous, and in some instances evidences are noticeable of a tendency among instructors in engineering schools to do the same. In view of the increasing attention given to industrial and trade conditions in the country at large and in the foreign trade, it will become increasingly desirable to give to the term "industrial engineering" its full significance. What, then are the elements entering into the composite structure of this branch of engineering? Scientific management is one but there are many others.

In answering the question one must decide to consider it either as a separate branch in which men may be engaged, as other men are engaged in civil, mechanical, electrical, etc., and for which special training may be given, or as a group of activities which may constitute a part of the work of civil, mechanical, or other engineers. A mechanical engineer must often give his attention to matters which are outside the field of applied physics, chemistry and other natural sciences, and which are purely industrial in character. So is it with other engineers. From the standpoint of engineering education, therefore, it seems better to adopt the second interpretation, and consider industrial engineering as it should be included in the work of all students, and particularly those in the mechanical group. The following list of topics constitutes the answer which the writer would give to the question.

A. Elements in the profession.

1. The Prospective Establishment: existing industrial conditions favorable or otherwise to the product; markets, as to location and method of reaching same; competition; possibilities of economical production; etc.
2. Location for the Enterprise: economy in transportation of raw material or product; local conditions bearing upon the process and shipping facilities.
3. Industrial Processes: intimate knowledge of various processes, including the equipment employed and costs of same; ability to compute cost of manufacture.
4. Financing the Enterprise: general principles must be understood, even if the engineer does not carry direct responsibility.
5. Organized Form of Company: characteristic features of the corporation and partnerships of the various types.
6. Plant Design, in its general features, including consideration of process, power demands, available power systems, etc.
7. Company Organization in its various ramifications to meet operating needs.
8. Management Methods in their varied forms.
9. Accounting Practice.

B. Considerations involved in education.

1. Fundamentals of Economics.
2. Special attention to Economics of Business, to be given by engineer-instructor.
3. Industrial Development, treated both historically and technically.
4. Statistical Studies, of manufacturing, transportation, power, labor.
5. Manufacturing Processes: real attention to be given to various kinds of manufacturing, in contradistinc-

tion to the confining of attention to the designing and construction of engines and other machines with which so many engineering schools are obsessed.

6. Economics of Power and Power Application.
7. Business Organization and Methods, with Contract Law.
8. Management Methods, in so far as they deal with fundamental principles.
9. Accounting, and valuation of properties.

While the language used in these lists is that pertaining to manufacturing industries, slight changes would render them equally descriptive of conditions in the lines of transportation and railway engineering, electric power production, mining, or other enterprises susceptible of technical analysis.

ADJUSTING EDUCATIONAL REQUIREMENTS TO SPECIAL APTITUDES.

BY J. R. BENTON,

Dean, College of Engineering, University of Florida.

The interesting and able article in the May BULLETIN by Mr. Sanford A. Moss, entitled "Aptitude as a Basis for Education," proposes a new solution to the old problem of adapting educational requirements to the peculiarities of individual aptitudes and tastes. The proposal is to offer two courses in each of the less important required subjects; one for students having aptitude in the subject, designed to give proficiency in the actual use of the subject; the other for students lacking aptitude in that subject, designed to give merely general knowledge *about* the subject. Students who take the latter course in any subject would do some additional work in other subjects for which they have aptitude.

Believing that proposals like that of Mr. Moss, as well as his treatment of the whole problem, are deserving of further discussion, I am venturing a few comments on his article.

An objection may be made to Mr. Moss's proposal, in that it seems to assume that, with reference to any given subject, all people are divided into two classes: those who have aptitude, and those who do not. As a matter of fact there are not simply two classes, but an infinite number, representing all possible grades of aptitude. The question whether a student benefits by pursuing some difficult study (assuming such study to be valuable in itself) is very largely a question of *how much* aptitude exists, rather than a question of presence or absence of any aptitude whatever. If a student is so lacking in aptitude for some subject that, despite earnest effort, he can accomplish practically nothing in it, no one would question the wisdom of his dropping it; or, on Mr. Moss's

plan, substituting a descriptive course not designed to give any actual proficiency in the subject. If, on the other hand, his aptitude is merely a little below the average, it would be poor educational policy to let him weakly give up, rather than make slightly more effort than his classmates find necessary. Even granting that such a student acquires only mediocre proficiency, this disadvantage is more than balanced by stimulating the spirit of overcoming, rather than evading, minor difficulties.

If this latter case—that of only slight lack of aptitude in some subject—were the only one, there would be no special problem. But the former case—that of serious lack of aptitude in some one subject—does occur; it occurs among students who do excellent work in most of their studies; and, while by no means as common as the case of slight lack of aptitude, it occurs frequently enough to deserve special consideration, as pointed out by Mr. Moss.

Granting all this, it is still debatable whether the problem is serious enough in the engineering colleges to justify such a change as Mr. Moss suggests. Most colleges do not actually *require* a student to take subjects for which he has no aptitude or taste, as a condition for *permitting him to attend.* Usually a student has this option: either to take a required curriculum and receive a degree; or else, to enroll as a special student, take a specified quantity of work of his own choosing, and not receive a degree. The question may well arise, how far it is worth while to modify the practice of the colleges for the sake of a few exceptional individuals lacking in certain aptitudes, when those same individuals are perfectly free to take those subjects in which they do have aptitude, merely by foregoing the matter of a degree, which has comparatively little influence on ultimate success. Nevertheless, this objection is more theoretical than practical, since in practice an effort is usually made to induce every student to take some regular curriculum; and since the degree, however unessential, is an object of ambition.

Despite such objections as those just raised, it will no doubt be generally admitted that there is a problem worth trying to solve, in adjusting the requirements for degrees to make proper allowance for variations in special aptitudes.

The problem is not a new one, but the only attempt to solve it that has had actual trial on a large scale is the elective system. And the elective system has not met with favor in engineering courses, and does not seem suitable for them.

The plan proposed by Mr. Moss, that of giving separate courses in certain subjects—one to gain proficiency, for students with aptitude, and one to gain general acquaintance with the subject, for students lacking special aptitude—seems theoretically sound, provided proper regulations are worked out to limit the courses in which the student may claim the privilege (as it would probably be regarded by some) of lack of aptitude. But practically this plan involves the difficulty of doubling the number of courses in some subjects. This would either overwork the instructors, or require the expense of employing additional ones.

It seems to me that this practical difficulty might be overcome, and the essential features of Mr. Moss's proposal still be secured, by the following plan:

Instead of having a single passing grade for all subjects, and requiring a student to obtain that grade in everything required in order to receive his degree, have two or more passing grades; require a higher grade in the more essential subjects, and allow the student to graduate with merely the lower grade in a certain number of the less essential subjects. To illustrate: Suppose that the percentage system of grading is used, and that it has been customary to require a passing grade of 75 in every subject in a certain curriculum in order to receive a degree. Under the plan now proposed, no change would be made in the curriculum or the courses of instruction offered; but in order to get a degree, the student would be required to get 85 (instead of 75) in the technical subjects of his specialty, in physics, and in mathematics below cal-

culus; he need make only 75 in chemistry and English; and only 60 in calculus, modern languages, and electives. Of course it will be understood that the figures and choice of subjects assumed here are merely by way of illustration.

Under this plan it would be assured that all graduates were better informed in their chosen specialties than when the single passing grade of 75 is maintained. At the same time, the graduates need not acquire a high degree of proficiency in the less essential subjects, but still would be held to some general acquaintance with them.

With such a system there should also be a requirement that the total average grade in all subjects should be above a certain minimum. Under the systems in general use it is possible for an indolent but able student to do just exactly the minimum demanded in every subject that he takes. The minimum or bare passing grade does not usually represent satisfactory work. Often it does not even represent the worst work that the instructor *intends* to recognize for passing; since instructors, fearing that their judgment in assigning grades may not be infallible, are likely to give the student the benefit of the doubt, when there is a doubt. This may do no great harm if only one subject is concerned, and the student in question does good work in other subjects. But it is very objectionable if similar inferior work is done in the other subjects. By requiring for graduation a general average grade somewhat higher than would correspond to bare passing in each individual subject, this difficulty could be overcome; and the requirements would be further adjusted to variations in special aptitudes, since a student could do rather poorly in some subjects, but would then be obliged to do correspondingly superior work in others.

REMARKS ON "INCOMES OF ENGINEERING GRADUATES."

L. H. RITTENHOUSE,

Associate Professor of Mechanical and Electrical Engineering,
Haverford College.

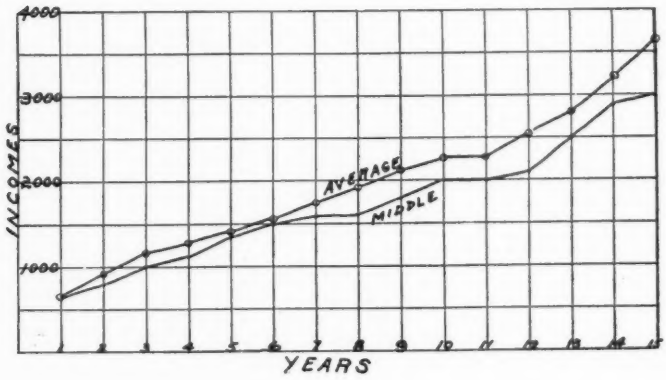
The article in the April BULLETIN by Dean Benjamin on "Incomes of Engineering Graduates" will undoubtedly cause much interest and reflection. It is always a pleasure to note these incomes (some running into five figures!), to construct charts and to study them, since many of us may not experience them in any other way.

The use of average values in charts showing incomes has always appeared to the writer to be misleading. At least it is capable of misinterpretation. The term "average income" suggests the income of the average man in the class, that is, the salary received by half the class or group. Again, inspection of the charts summarizing results (as No. 13 in Dean Benjamin's article) might lead to the conclusion that any unit (graduate) had an even chance of obtaining the incomes shown for the respectives years. Both of these conclusions are wrong, since usually *less* than half of each group receives the average income. The curves as drawn, of course, are correct and the values are true *averages,* but they may be easily misapplied as shown above.

I would suggest the use of the "middle income"; *i. e.,* the maximum income received by one half the class. That there is considerable difference in some instances, between the "average" and the "middle" income is shown by the accompanying curves, Fig. 1. These curves were plotted as nearly as possible from the values as read from the chart No. 3 (1899 mechanical engineers). For example, at 8 years the true

average is $1,940, as given by the author, while the *middle* value is about $1,600. The difference of course is due to the fact that nearly always there are one or two very high incomes and they pull up the average.

The *purpose* of the charts should determine the proper figures to plot. While no purpose is usually stated in presenting income statistics, we may presume that it is a satis-



faction to the alma mater to determine her gross product financially (and the *average is* a measure of this) but the individual alumnus, as well as the prospective alumnus would undoubtedly find the "middle" a more instructive figure. If the college authorities are looking for a "yard stick" with which to measure their product, it seems even in this case that "middle" values would be in order. One superfine unit cannot make up for nine poor units although the average may be good.

The writer takes exception to Dean Benjamin's *conclusion* in regard to the "claim that a partial return is apt to show too high values, on the ground that those who do not reply are the ones having small incomes." The writer is one who believes this "claim" to be true. Dean Benjamin states: "As far as ob-

servations go, this is *not* true in the present case. The departments from which came the smaller percentage of replies show lower averages than the others. This may be accidental, but it is evidence as far as it goes." It appears to me that the evidence shows that the "claim" *is* true, rather than *not* true. To illustrate, let us consider two classes of seven men each, receiving incomes as follows: Class A—22, 20, 18, 16, 14, 12 and 10 hundred dollars respectively. Class B—18, 16, 14, 12, 10, 8 and 6 hundred dollars respectively.

Following our assumption that "small incomes" do not reply, let us omit from calculation all incomes of $1,200 and less. The result is: Class A, average, $1,800. Per cent. replying, 71. Class B, average, $1,600. Per cent. replying, 43.

It will be seen that this illustration fits the case Dean Benjamin referred to: *i. e.*, the smaller percentage of replies show lower averages. But it will be further noted however that B's average is 33⅓ per cent. *too high*. The true average of class B is $1,200, whereas the incomplete returns show $1,600.

The above bears out our contention that partial returns tend to show too high values. Figures of course could be presented bringing out the contrary result but not if we follow our premise that "small incomes are missing" and strike out all incomes below a certain minimum.

Dean Benjamin's aside remark in reference to some being very dilatory in their replies, suggests the thought that a great many of those who failed to reply might raise their incomes by just a little more attention to details and to promptness.

DISCUSSION: AN EXPERIMENT IN THE EVALUATION OF AN INTEGRAL.

BY THE AUTHOR.

To the Editor,

Dear Sir: I have received your letter of May 31 with its enclosure from Dr. William Kent. I have received other communications which also seem to misunderstand the purpose of the experiment described in my article in the May number of Engineering Education.

I tried to make it clear that I was not in any sense in search of "quickest" methods for solving the problem described. I knew, of course, that by using special tables and formulæ (Simpson's rule, for example) the result could be got accurately and much more rapidly.

My purpose was to emphasize the meaning of integration as a summation to a class in mathematics, and at the same time to show them that there are several ways in which to apply those principles; some ways better and quicker than others.

I should strongly deprecate the use and teaching of more or less artificial rules and formulæ to such a class. Such rules are apt to be forgotten or misapplied, whereas the capacity to *think* in mathematics and to attack its problems from the point of view of a knowledge of the principles of the science is not only more lasting but also more valuable not to the student only but to the engineer also.

I was interested also in the relative times of the three methods both in my own work and the work of the students, but not particularly in the actual times. My own work, which as I said was done with diligence but without haste, I called a *standard;* meaning thereby a standard of results and times for my students.

If you think it worth while you may publish this letter in

ENGINEERING EDUCATION, or you may forward it at your discretion to Doctor Kent, to whom I should like to express my appreciation of his interest in my article.

Very truly yours,

LEONARD M. PASSANO.

REPORT OF THE AUDITING COMMITTEE.

NEW YORK CITY,
September 13, 1916.

EXECUTIVE COMMITTEE,
Society for the Promotion of Engineering Education,
University of Pittsburgh, Pittsburgh, Pa.

Gentlemen: Acting under authorization from your Committee, we have examined the books and accounts of the Treasurer of the Society for the Promotion of Engineering Education for the fiscal year ending July 1, 1916, and certify that in our opinion the funds of the Society have been fully and faithfully acounted for and are pleased to report that we found the books to be correct and in good order.

Respectfully submitted,
Auditing Committee,
ARTHUR H. BLANCHARD, *Chairman,*
C. R. MANN,
HENRY H. NORRIS.

EDITORIAL.

The paper by Professors Hanus and Gaylord appearing in this number of the BULLETIN brings to our attention again the old questions which always confront every good teacher, that is, the material which he should present and the manner in which it should be presented. The necessity of requiring all engineering students to take the same course in certain subjects such as calculus confronts the teacher with the dilemma of teaching in the same way a man who is to be a future designer, to whom the calculus is to be a friend and a tool; a man who is to be a manager of men, to whom calculus will appear only as a visionary subject taken somewhere in his course because it was required and who will remember it only because the professor was so very particular in regard to the solution of problems; and near him a young man who will be a consulting engineer and who must retain a general knowledge of his calculus in order that he may check the work of others and his subordinates. It is the teacher's problem to so present the calculus that it will be a real tool to the designer, training to the manager, and training and a tool to the consulting engineer.

Of course, the problem of teaching such subjects would be immensely simplified and clarified if we could determine during the freshman year or before what each of the young men entering that class will grow up to be, *i. e.*, a consulting engineer, a designer, or a manager, etc. But this under our present conditions is entirely impossible so that the teacher is confronted with a many sided problem, the solution of which seems to be to teach in all of these subjects the underlying principles upon which that subject and its relation to engineering is based, in such a way as to permit each and every student to develop later in life to the fullest extent of which he is capable.

ADDITIONAL COMMENTS ON THE VIRGINIA MEETING.

The University of Virginia with its cordial welcome and hospitality and with what I like to call its Jeffersonian architecture, will be the source of very pleasant recollections to me. The proceedings of the Society were of considerable value and I have but one criticism, *i. e.*, that the report on the teaching of electrical engineering was sadly slighted.

L. A. DOGGETT.

In my opinion the Virginia meeting of the S. P. E. E. was the best that I ever attended. There was considerable "snap" about the proceedings and the social features were most enjoyable. I think the scheme of doing work by committees is going to be a success. J. A. L. WADDELL.

The University of Virginia is a place of educational traditions and of natural beauty which every teacher must be impressed by and should visit. The convention proved the hospitality of the engineering and other staff of the University to be in fact all that it is reported to be. The business of the convention was interesting and proved the worth of the new committee plan. DUGALD C. JACKSON.

The feature most noticeable throughout the meeting at Charlottesville was the display of a fixed purpose that the efforts of prospective engineers to obtain their college training shall be most efficiently directed and guided.

E. F. CHANDLER.

The discussions at Virginia were to the point. I like papers which lead to action, and the committees' reports make this possible. The trip to Monticello and the outlining, by Dr. Mann, of the big problem before the engineering teacher and administrator, stand out as high points at the meeting.

ARTHUR J. WOOD.

In my opinion the Virginia meeting was well planned and well conducted. The program was excellent and the papers

and discussions were very helpful. The social arrangements made by the local committee added much to the interest of the meeting, and the opportunities for making and renewing friendships were especially appreciated.

H. L. HODGKINS.

The meeting was inspiring and pleasant. The arrangement of work by committees is a good thing. But there is room for improvement in saving time at the sessions. *Every* committee should be represented by the chairman or another member who will present a brief summary of the report to start the discussion—not read the entire report which is already in everyone's hand. Time should be allotted, in advance, so the program would not be overcrowded, and so that those forced to arrive late or leave early could know just when certain discussions would take place.

O. M. LELAND.

It is desirable to meet at some educational institution and to have papers like that of Professor Bird on "The Teaching of Chemistry at the University of Virginia," preferably from the university at which we are meeting.

D. C. HUMPHREYS.

The most interesting part of the meeting was the contact with the members who were present. A chance to compare methods and get new viewpoints.

W. H. ADAMS.

I found it possible to attend but a single session but I so enjoyed the discussions that I regretted the more my absence from the other sessions. I was particularly impressed with the broad conception of education held by the Association.

CHAS. W. KENT.

As regards my impression of the Virginia meeting, let me say that the thing I most enjoyed, as is always the case with the meetings of the Society, was the contact with keen minds. I know of few meetings where I come away so mentally re-

freshed as from the meetings of the Society for the Promotion of Engineering Education.

HOLLIS GODFREY.

The spirit of the meeting was that of the *man*, Thomas Jefferson, and the *institution* which he founded one hundred years ago—*The University of Virginia;* personal honor before individual advancement, human interest ahead of material development.

C. L. CORY.

The meeting was to my mind a very enjoyable and profitable one. The papers and discussions were distinctly above average. The opportunity to renew old acquaintances and to make new ones was alone well worth the time and expense of the trip and I left Charlottesville with an enhanced sense of the value and importance of the Society.

It is a matter of sincere regret that so few found time to take the trip to Richmond, Jamestown and Williamsburg, which had been arranged. I think that all those who did go will sustain me in saying that this was one of the most profitable and enjoyable features of the convention. Those who failed to go missed a delightful experience.

JOHN A. DENT.

NEW MEMBERS.

BAUM, WM., Dean, Electrical Engineering Department, School of Engineering of Milwaukee, Milwaukee, Wis.

BRASEFIELD, S. E., Professor of Applied Mathematics, Rutgers College, New Brunswick, N. J.

TAYLOR, K. M., President, Taylor-Wharton Iron & Steel Co., High Bridge, N. J.

APPLICANTS FOR MEMBERSHIP.

MATHESON, K. G., President, Georgia School of Technology, Atlanta, Ga. Hollis Godfrey, F. L. Bishop.

PERSONAL.

J. F. Wilson, formerly instructor in electrical engineering at the University of Michigan, has been appointed professor of electrical engineering at Queen's University to take the work of Professor L. W. Gill while the latter is in active military service.

BOOK REVIEW.

Bridge Engineering. By J. A. L. WADDELL. First edition. John Wiley and Sons, New York. Two volumes, octavo, cloth. Price $10.00 net.

This monumental work of 2,250 pages embodies the conclusions of the authors' many years of practice. To mention here even the titles of its 80 chapters is impracticable, suffice it to say that they cover the whole range of bridge engineering, except the computation of stresses as given in text-books. Surveys, location, dredging, foundations, piers and abutments, materials, inspection and erection are well treated. Æsthetics and ethics, specifications and contracts, principles of designing, details, and office practice are ably discussed. In separate chapters are covered plate girders, simple trusses, trestles, elevated railroads, cantilevers, arches, suspension bridges, moveable structures and reinforced-concrete bridges. Five chapters are devoted to loads, and two of especial value to the weights of steel superstructures and to the quantities required for piers and reinforced-concrete structures. The work is well illustrated; there are 316 ordinary figures, several of these being full-page and folding plates of bridge details; 188 cross-section diagrams for loads, weights, and quantities for different styles and spans of bridges; and 68 photographic views. There are also 90 valuable tables for use in designing. This very important work contains a vast amount of matter, presented in clear and logical form, which cannot fail to be of great value to all bridge engineers and also to students in engineering colleges.

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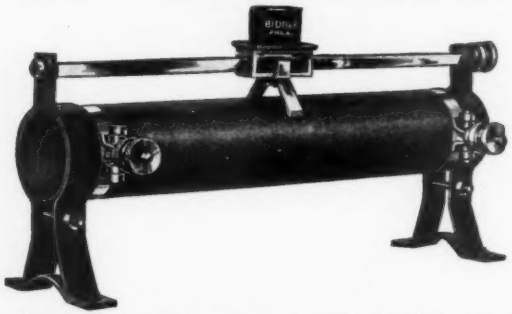

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